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Role of Machine Vision System in Food Quality and Safety Evaluation

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ABSTRACT

In India the ever-increasing population, losses in handling and processing and the increased expectation of food products of high quality and safety standards, there is a need for the growth of accurate, fast and objective quality determination of these characteristics in food products continues to grow. Number of mechanized processing lines has been developed for commercial production. But the visual inspection and quality control is done by human eyes. Human inspection is a slow process, has poor repeatability and result varies from person to person. Machine vision system (MVS) is an image processing/analysis technique which is used for objective evaluation of quality parameters. Its speed and accuracy satisfy ever increasing production and quality requirements, hence aiding in the development of totally automated processes. Mass production of food was also associated with two major problems. The first one is the decline in food quality, and the second one is the "waste" problem associated with processing and preparation operations. The wastage in many cases is a direct consequence of the quality problem, where the quality decline reaches unaccepted limits. Hence, is the need for quality inspection and assurance mechanisms to be installed in the production lines of such mass food processing and producing plants.

MVS can perform many functions simultaneously in a food processing line such as segregation by species, by size, by visual quality attributes, determination of composition, volume, measurement of shape parameters, and quantification of the meat colour, automated portioning and detection of defects. MVS system is also being used in food industry for the detection of defects in apples, oranges, olives, cherries etc., sorting of potatoes, online monitoring of baking conditions, measurement of browning in chips. It is also being used for checking ripening stages of banana, tomato, cherries etc. Also it can be used to classify different varieties of cereal grains and check their adulteration. MVS considered as investigative tool to evaluate the functional properties and quality attributes such as shrinkage, texture and colour of cheddar and mozzarella cheese. This paper critically reviews the progress and application of MV technology in the food industry with a special emphasis on meat, poultry, seafood, and other foods. Recent developments in MVS and supporting technologies has resulted in general acceptance of the feasibility and profitability of implementing visual inspecting systems in quality assurance operations.

Keywords: *Machine Vision System ; Image Processing; Food Sector; Sensor; Quality; Safety.*

1.0 Introduction

Machine vision is becoming one of the most important non destructive, rapid, economic, consistent and objective inspection and evaluation technique in the food industry (Gumus et al., 2011). This inspection approach is based on image analysis and processing and has found a variety of different applications in the food industry.

Considerable research has highlighted its potential for the inspection and grading of fruits and vegetables based on shape, size and color. Computer/ Machine vision also has been successfully adopted for the quality analysis of meat and fish, pizza, cheese, and bread.

Likewise grain quality and characteristics have been examined by this technique (Brosnan & Sun, 2002).

A machine or computer vision system can be used as low cost alternative to colourimeters and spectrophotometers. In machine vision system (MVS) image capturing devices or sensors are used to view and generate images of the samples. Some of the

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devices or sensors used in generating images include charged coupled device (CCD), scanners, and ultrasound, X-ray and near infrared spectroscopy.

The colour image is analyzed by a computer program/software and quantifies colour values in a relevant colour scale (Minz et al., 2013). As a result automated visual inspection is undergoing substantial growth in the food industry because of its cost effectiveness, consistency, superior speed and accuracy (Lochtetal, 1997 and Sun, 2000).

2.0 Components of Machine Vision System

Machine or computer vision is the construction of explicit and meaningful descriptions of physical objects from images. It encloses the capturing, processing and analysis of two-dimensional images; with others, noting that it aims to duplicate the effect of human vision by electronically perceiving and understanding an image. A machine vision system consists of four basic components, which are image illumination, image acquisition, frame grabber and image analysis.

2.1 Image illumination

Illumination systems are the light sources. The light focuses on the materials (especially when used). Lighting type, location and colour quality play an important role in bringing out a clear image of the object (Narendra and Hareesh, 2010).

2.2 Image acquisition

With advances in digital cameras, the camera and the image capture system generally merge into a single device. This device communicates with the computer via cables (e.g., USB or Fire wire), or by wireless means. There can be three light detection sensors in the camera, dedicated to each primary colour (Red, Green, Blue), or one sensor can be selectively used to handle all the three primary colors. The software can control the camera settings, the timing of image acquisition, the light source and can analyze the image to extract desired features to make decisions. These may include non-contact sensing, measuring object shape and dimensions, detecting product defects; providing process control feedback alerting production line operators for in process system failures; and providing product quality statistics (Sarkar, 1991; Sun, 2004; Balaban et al., 2005).

2.3 Frame grabber

The features of a frame grabber required for machine vision applications include image acquisition, camera control and image data pre-processing. The frame grabber can acquire either digital or analog images depending on the camera used. For camera control, a minimum requirement is accurate A/D circuitry and precise camera timing. Input signal conditioning such as the ability to control gain and offset, is important to minimize effects from camera variability or lighting fluctuations (Chen et al., 2002). Also, some frame grabber boards are capable of pre-processing imaging with functions such as "First-In-First-Out" (FIFO) and "Look-Up Table" (LUT). A modem frame grabber board can communicate with the host CPU's memory via software driver at speeds of 80-130 Mbytes/s. This speed is appropriate to meet the needs of many real time operations in food industry.

2.4 Image analysis

Image analysis can provide a wide range of information about a product from a single image in a fraction of a second, making it possible to analyze products as they pass on a conveyor belt (Storbeck and Daan, 2001). Image processing/analysis involve a series of steps, which can be broadly divided into three levels: low level processing, intermediate level processing and high level processing (Sun, 2000).

2.4.1 Low level processing

Low level processing includes image acquisition and pre-processing. Image acquisition is the transfer of the electronic signal from the sensing device into a numeric form. Image preprocessing refers to the initial processing of the raw image data for correction of geometric distortions, removal of noise, grey level correction and correction for blurring. Averaging and Gaussian filters are often used for noise reduction with their operation causing a smoothing in the image but having the effect of blurring edges.

2.4.2 Intermediate level processing

Intermediate level processing involves image segmentation, image representation and description. Image segmentation is one of the most important steps in the entire image processing technique as subsequent extracted data are highly dependent on the accuracy of this operation. Its main aim is to divide an image into regions that have a strong correlation with objects or areas of interest.

2.4.3 High level processing

High level processing involves recognition and interpretation, typically using statistical classifiers or multilayer neural networks of the region of interest.

These steps provide the information necessary for the process/machine control for quality sorting and grading. Statistical procedures from basic image statistics such as mean, standard deviation and variance to more complex measurement such as principle component analysis can be used to extract features from digital images.

Once image features are identified, the next step is feature classification. (Minz, 2013)

3.0 Application of Machine Vision in Quality and Safety Evaluation in Dairy and Food Industry

The system offers the potential to automate manual grading practices thus standardizing techniques and eliminating tedious human inspection tasks. Machine vision has proven successful for the objective; online measurement of several food products with applications ranging from routine inspection to the complex vision guided robotic control (Gunasekaran, 1996).

3.1 Quality and safety evaluation of fruit and vegetables

Shape, size, colour, blemishes and diseases are important aspects, which need to be considered when grading fruits and vegetables (Kanali et al., 1998; Chatli et al, 2013 and Mahendran et al., 2013). Colour provides valuable information in estimating the maturity and examining the freshness of fruits and vegetables. The automated inspection of produce using machine vision not only results in labour savings, but can also improve quality inspection objective (Kanali et al., 1998). Machine vision is being implemented for the automated inspection and grading of horticulture produce to increase product throughput and to improve objectivity of the industry (Brosnan and Sun, 2002).

Narendra and Hareesh (2010) reported variety classification, defects detection and segmentation, identification of stems and calyxes and sugar content prediction in apples. They also investigated the use of computer vision in sorting fresh strawberries based on size and shape, shape characteristics of papaya, tomato color, size, shape and abnormalities with inner quality, inspect and grading of mushrooms, separation method for grading of potatoes, color of lemon. Marakeby et al., (2013) also studied on fast quality inspection of food products using computer vision.

Arjenaki et al. (2013) sorting the tomato online based on shape, maturity, size, and surface defects using machine vision. Silvia (2011) reported quality assessment of blueberries by computer vision. Sadegaonkar (2013) evaluated the quality Inspection and grading of mangoes by computer vision & image analysis. The algorithm was able to identify ripened tomato by high accuracy in different lighting conditions of greenhouse (Arefi, 2011).

Golmohammadi (2013) developed a machine vision system for online evaluation of potato sorting. To separate potatoes, an accelerator system based on Pneumatic control valves and air pressure was used. As the system is online, all of timings related to image processing, product transferring and accelerators operation were calculated and applied based on the speed of the potatoes being fed to processing and sorting system. For the primary evaluation of the system, 100 kg of potatoes were manually sorted into three categories. Then the same potatoes were fed to the system, which sorted them out with an accuracy of 97.4% with the speed of two potatoes per second.

Rajin et al. (2013) evaluated the quality of grapes using non-destructive machine vision system. Singh and Kamal (2013) used Machine Vision System for Tea Quality Determination based on Tea Quality Index (TQI)

Gumus et al. (2011) identified the aquatic food processing line based on sorting by species, by size, and by visual quality attributes, as well as automated portioning. Aquatic foods is grouped as determination of composition, measurement and evaluation of size and volume, measurement of shape parameters, quantification of the outside or meat color of aquatic foods, and detection of defects during quality evaluation. It can provide fast identification and measurement of selected objects, perform quality evaluation of aquatic foods, and their classification into categories based on shape, size, color and other visual attributes.

3.2 Quality and safety evaluation of beverages

The classification of beverages was conducted using three approaches: by using the electronic nose only, by using machine vision alone and by using the combination of electronic nose and machine vision. A supervised support vector machine was used to classify beverage according to their brands. Results show that by using the electronic nose alone and machine vision alone were able to respectively classify 73.7% and 92.9% of beverage correctly. When combined the electronic nose and machine vision, the classification accuracy increased to 96.6%. Based on results, it can be concluded that combination of both is able to extract more information from sample, hence improving the classification accuracy. (Mamat et al. 2012)

3.3 Quality and safety evaluation of meat, poultry and fish products

Machine vision application in meat industry can be grouped as: determination of composition, fat/muscle ratio, measurement and evaluation of size and volume, measurement of shape parameters, quantification of the outside or meat colour, and detection of defects during quality evaluation. Moisture and fat content of meat has been correlated with the colour (Chen et al., 2002) Several companies have developed water-jet cutters that employ three-dimensional machine vision systems to calculate volume. The volume dictates where the cutting should take place in order to obtain the optimal yield from a piece.

Hu et al. (2012) classified Fish species by color, texture and multi-class support vector machine using computer vision. Tan et al. (2000) described the Assessment of fresh pork color with color machine vision. Vote et al. (2003) predict the online beef tenderness using a computer vision system equipped with a Beef Cam module.

Online poultry inspection by a multi-camera system can be employed to accurately detect and identify carcasses unfit for human consumption (Chen et al., 2002). By automating this process, the level of accuracy in identifying defective eggs increases; and the rate of sorting is higher. The 1.4 Megapixel cameras are positioned in such a fashion as to capture images from every angle as the eggs roll down a conveyor belt. The cameras monitor the quality of eggs passing through the system and the images are analyzed digitally, with complex algorithms identifying any hairline cracks or detritus on the egg's surface.

3.4 Quality and safety evaluation of bakery/ snacks/confectionaries products

Davidson et al. (2001) measured the physical features of chocolate chip biscuits, including size, shape baked dough colour, and fraction of top surface area that was chocolate chip using image analysis. Vision systems have been used in inspection applications ensuring that moulds used in the production of confectionery are empty and properly cleaned. The internal and external appearances contribute to the overall impression of the products quality consequently such characteristics have been evaluated by computer vision. Scott (1994) described a system which measures the defects in baked loaves of bread, by analyzing its height and slope of the top. The internal structure (crumb grain) of bread and cake was also examined by machine vision (Sapirstein, 1995). The brightness, cell density, cell area and uniformity of the grain analyzed indicated that even the most minor deviations from the required specifications can be identified through machine vision system, allowing corrective measures in the bakery to be taken sooner. In a more recent study, digital images of chocolate chip cookies were used to estimate physical features such as size, shape, baked dough colour and fraction of top surface area that was chocolate chip (Davidson, Ryks and Chu, 2001). Nia (2012) investigated the Physical Characteristics of Bread using machine vision. Machine vision can be used to: Classify objectively potato chips according to their colour in different categories, Identify broken crackers. Determine edge. Ensure uniform baking/cooking and colour development Detect defects in colour, shape, topping and packaging Find pizza topping percent and distribution (Sun, 2000) Visually inspect chocolate chip cookies and muffins. A prototype-automated system for visual inspection of muffins was developed by Abdullah et al. (2000) and they reported that it was able to correctly classify 96% of pre graded and 79% of ungraded muffins with an accuracy of greater than 88%. Now, the machine vision system has also been used in the assessment of quality of crumb grain in bread and cake products (Sapirstein, 1995).

3.5 Quality and safety evaluation of processed food products

Visual features such as colour and size indicate the quality of many prepared consumer foods. Patel et al. (2012) and Sun (2000) investigated this in research on pizza in which pizza topping percentage and distribution were extracted from pizza images. Then it was found that the new region-based segmentation technique could effectively group pixels of the same topping together and the topping exposure percentage can be easily determined with accuracy 90%. To avoid the misguideness of quality assessment by visual based human perception, computer vision has been widely used in the assessment of confectionary products so far.

3.6 Quality and safety evaluation of cereals

Quality inspection of cereal grains and pulses like rice, corn, wheat, gram, beans, etc., can be performed based on size (length/width) and color quantification of samples. Machine vision systems are being used to sort grains falling off the end of a conveyor belt. The cameras capture images as the beans are in mid-air, identify the produce that do not meet the quality standards and direct

Classification of types Disease infection Weed identification Size (whole and broken kernel) Whiteness and grading Heat damage analysis, Degree of milling, yield and percentage whole.

Narendra and Hareesh (2010) used machine vision to identify different variety of wheat and to discriminate wheat from non wheat components, developed a machine vision algorithm for corn kernel mechanical and mould damage measurement and whiteness of corn has been measured by on line computer vision approach, measuring the degree of milling of rice.

3.7 Role of MVS in automatic process monitoring

Application of machine vision has been reported for controlling drying process of sliced apple (Fernandez et al., 2006). The vigilance of a drying process was provided due to online image analysis and correlation of image attributes (area, colour and texture) with physical parameters of drying (moisture and quality). A relationship between area shrinkage and moisture content was used for online estimation of actual moisture content. A relationship between color intensity and quality was used for online estimation of quality degradation during drying of ginseng roots (Martynenko, 2006).

3.8 Role of MVS in packaging/product integrity

Machine vision can also be used in product integrity verification to provide a comprehensive solution for any particular packaging line monitoring. It may verify the shape of a container or the correct position of a label and its registration (Zeuch, 2002). Inevitably it will also be required to do some form of pattern recognition in order to verify that it is the correct label. In addition, it will also be necessary to ensure that the package and label are aesthetically pleasing: there is no spill onto the outer packaging walls, that the label is not torn or wrinkled, or has no folded comers, etc. Strickland (2000) reported the use of digital imaging technology for the automatic monitoring of dry sugar granules and powders. This system provides particle size data to production line operators for process control and product quality improvement.

3.9 Role of MVS in identification of foreign objects

The detection of foreign objects and contaminants in food is a critical safety task. A machine vision system is much more effective at this task than human observers that can automatically detect foreign matter along the way. First, the vision system continuously watches the product stream and does not become distracted. Second, the vision system can freeze motion on a relatively high-speed belt, and its resolution can be specifically tailored for the observation task at hand (Minz, 2013).

4.0 Conclusion

A conceptual framework of machine vision system has its potential application for automatic food quality evaluation which is quite useful for Indian food and beverage industry in today's quality conscious and competitive world. A framework for machine vision system embedded with the emerging artificial intelligent techniques like artificial neural network, fuzzy system, genetic algorithms, expert systems, etc., for developing advanced vision systems for better efficiency/precision. Various aspect of food quality such as product quality and safety; classification and sorting; and process automation have much need in future for implementation of machine vision system.

References

[1] B. Gumus, M. Balaban, M. Unlusaym, Machine vision applications to aquatic foods: A Review. Turkish Journal of Fisheries and Aquatic Sciences, 11, 2011, 171-181

[2] T. Brosnan, D. Sun, Inspection and grading of agricultural and food products by computer vision systems-a review. Computers and Electronics in Agriculture, 36, 2002, 193-213

[3] P. S. Minz, A. K. Sharma, P. N. Raju, Application of machine vision system for quality evaluation of dairy and food products. National training on Innovative approach in processing and packaging of milk and milk products organized by NDRI, Karnal, 2013, 232-238 [4] P. Lochtetal, K. Thomsen, P. Mikkelsen, Full color image analysis as a tool for quality control and process development in the food industry. In: ASAE Annual International Meeting, St. Joseph, Michigan, USA: ASAE, 1997, 973006

[5] D. W. Sun, Inspecting pizza topping percentage and distribution by a computer vision method. Journal of Food Engineering, 44, 2000, 245-249

[6] V. G. Narendra, K. S. Hareesh, Quality inspection and grading of agricultural and food products by computer vision- A review. International Journal of Computer Applications, 2, 2010, 43-65

[7] N. R. Sarkar, Machine vision for quality control in the food industry. In: D.Y.C. Fung., R.F. Mathews (Eds.), Instrumental Methods for Quality Assurance in Foods, ASQC Quality Press, Marcel Dekker Inc. New York, 1991, 166-188